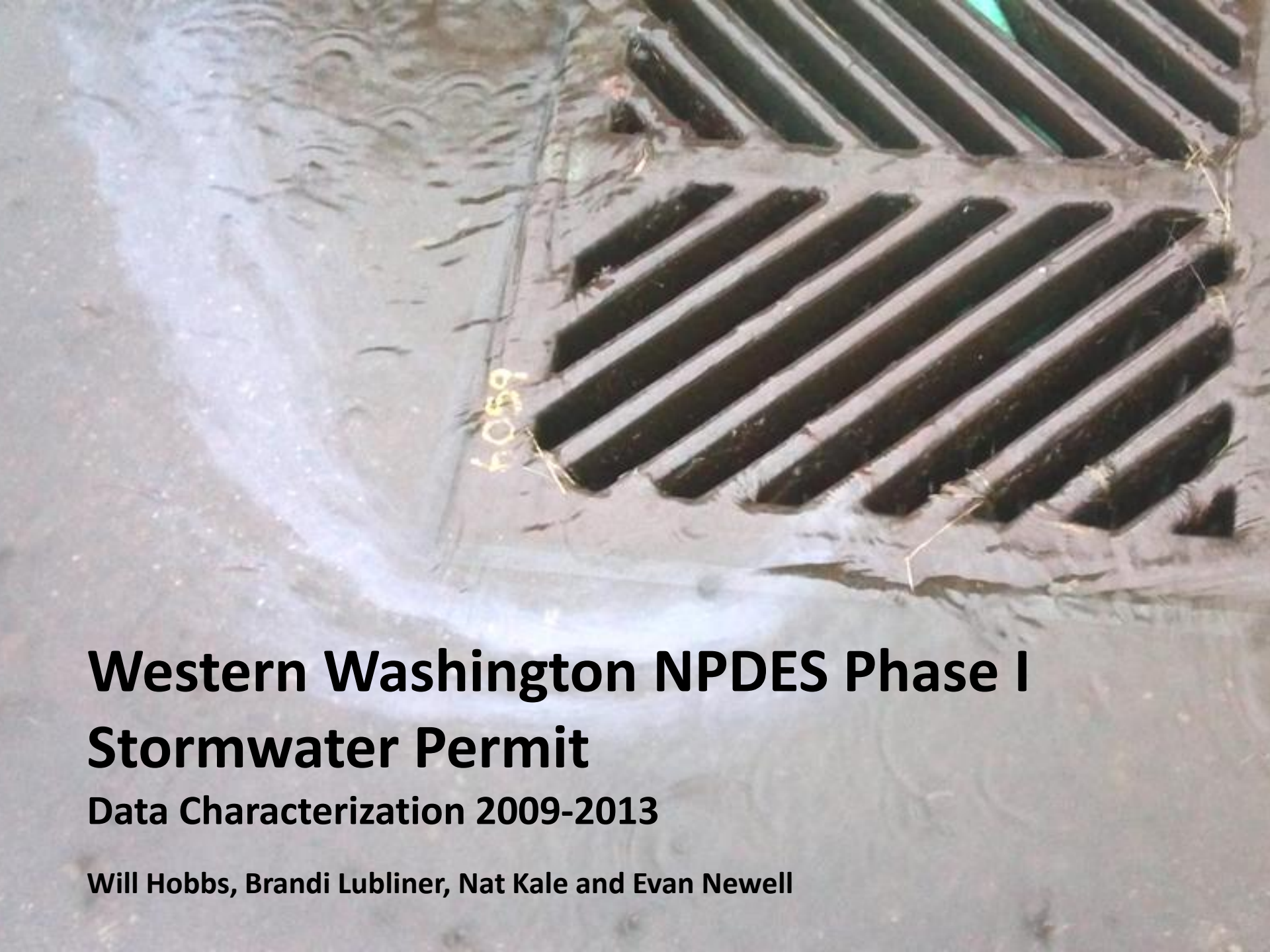


Western Washington NPDES Phase I Stormwater Permit

Data Characterization 2009-2013

Will Hobbs, Brandi Lubliner, Nat Kale and Evan Newell

Acknowledgements

- ***City of Seattle***
- ***City of Tacoma***
- ***Clark County***
- ***Port of Seattle***
- ***Port of Tacoma***
- ***Snohomish County***
- ***Pierce County***
- ***King County***

- ***Washington State Department of Ecology*** staff:
  Rachel McCrea, Ed O'Brien, Vince McGowan, Nancy Winters, Randall Marshall, Abbey Stockwell, and *James Maroncelli* for reviewing the draft report.
  Adam Oestreich for data QC and EIM support
  Dale Norton, Environmental Assessment Program (EAP), for project guidance.
  Jean Maust and *Joan LeTourneau*, EAP, for formatting and proofing the final report.
- ***Dennis Helsel*** (Practical Stats, Inc.) for statistical assistance.

Outfall Monitoring – 2007 to 2013

outfalls were selected to characterize **land use**:

- Industrial
- Commercial
- High-Density Residential
- Low-Density Residential

the goal was :

- to collect data that could be **generalized**
- to **establish a baseline** for potential future trends analysis

Permittees

- Clark County
- King County
- Pierce County
- Snohomish County
- City of Seattle
- City of Tacoma
- Port of Seattle
- Port of Tacoma

Required Monitoring Program Elements

required to collect **composite storm samples**, and some grab samples

up to **11** samples per year, with **60-80%** wet season and **20-40%** dry

variety of parameters including:

- **precipitation** data
- **conventional** parameters (TSS, conductivity, BOD, hardness, etc.)
- **nutrients** (phosphorus and nitrogen parameters)
- **metals** (copper, zinc, cadmium, lead, mercury)
- **organics** (PAHs, phthalates)
- **pesticides**

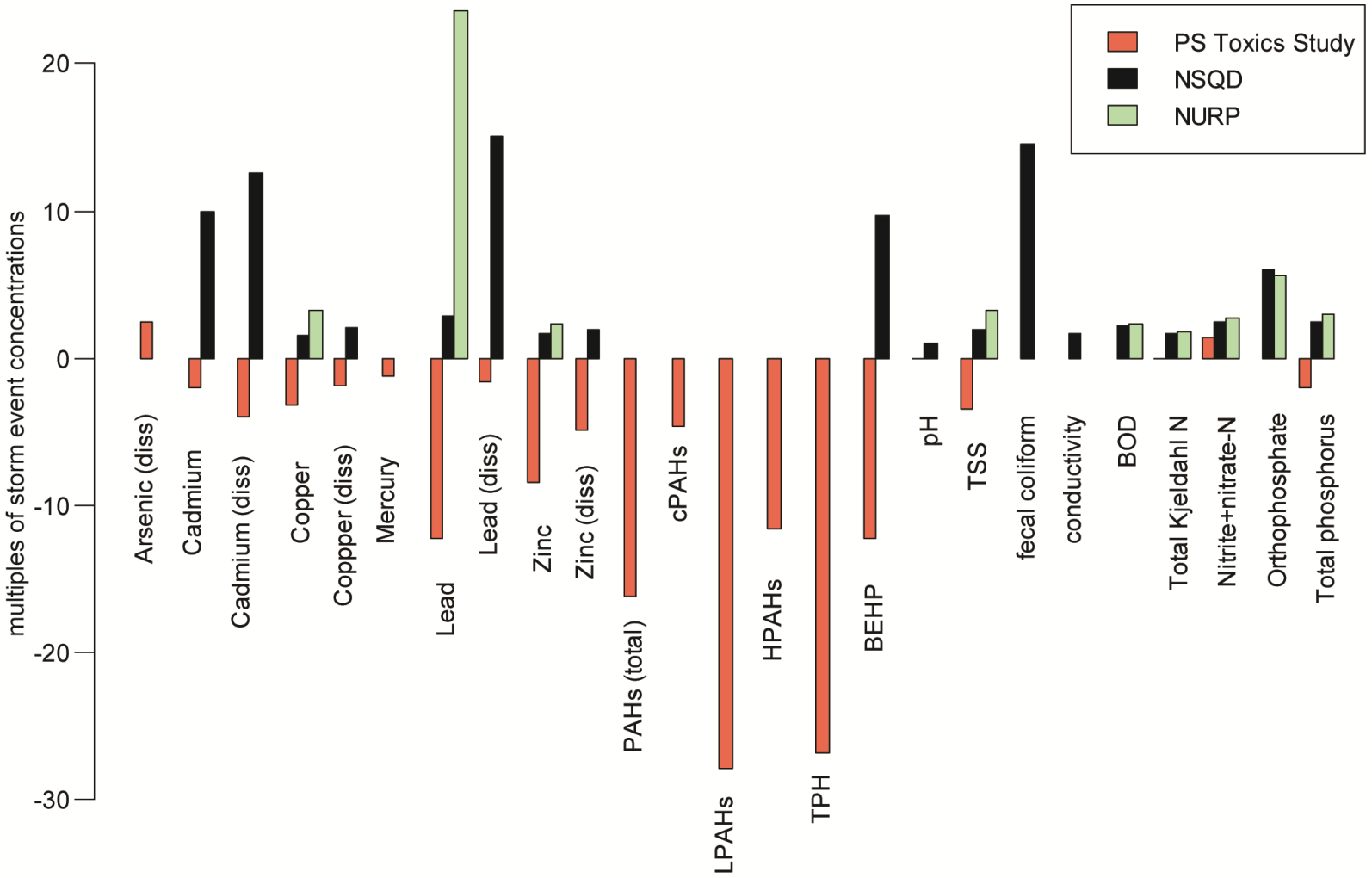
Final Dataset

49,000 Records; 60 Columns

A5428 | fx | Copper

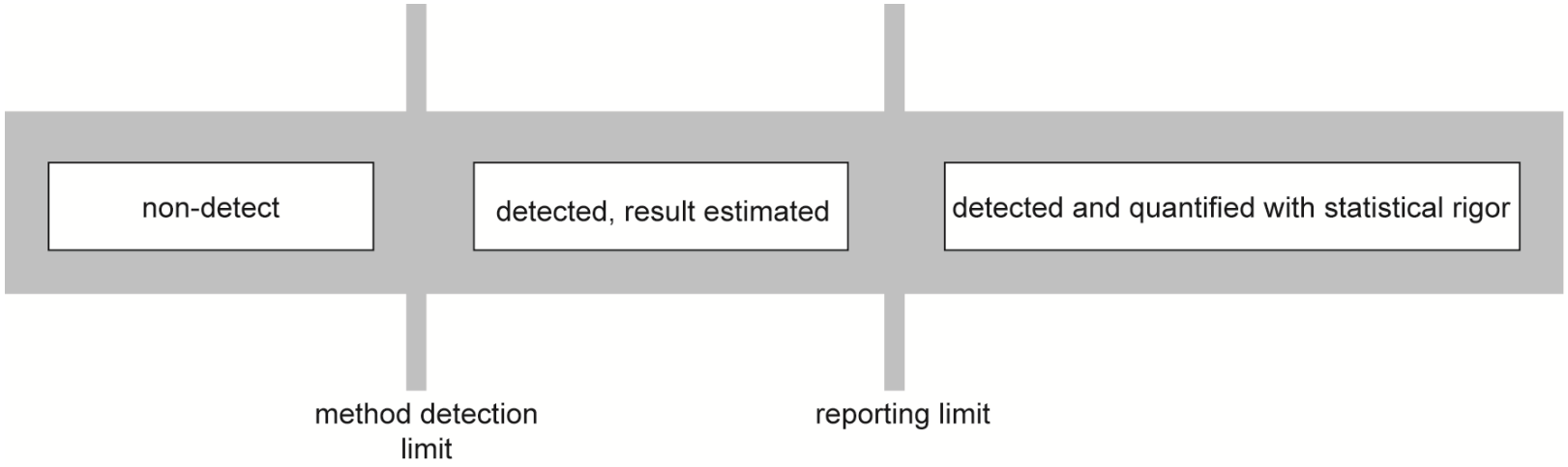
	A	B	C	D	E	F	G	H	I	J	K	L
1	Parameter	plot_data	paramStat	paramClas	paramGroup	Type	nonDetec	Access_ID	new_Resu	new_Resu	new_Fract	Study_ID
5428	Copper	TRUE	Include	Inorganic	Metal	COM	FALSE	5493	14.4	ug/L		WAR0447(
5429	Cadmium	TRUE	Include	Inorganic	Metal	COM	FALSE	5494	0.339	ug/L		WAR0447(
5430	Cadmium	TRUE	Include	Inorganic	Metal	COM	FALSE	5495	0.278	ug/L	Dissolved	WAR0447(
5431	Copper	TRUE	Include	Inorganic	Metal	COM	FALSE	5496	8.14	ug/L	Dissolved	WAR0447(
5432	Zinc	TRUE	Include	Inorganic	Metal	COM	FALSE	5497	27.7	ug/L	Dissolved	WAR0447(
5433	Zinc	TRUE	Include	Inorganic	Metal	COM	FALSE	5498	32.9	ug/L		WAR0447(
5434	Lead	TRUE	Include	Inorganic	Metal	COM	FALSE	5499	0.125	ug/L	Dissolved	WAR0447(
5435	Chloride	TRUE	Include	Inorganic	Conventional	COM	FALSE	5500	900	ug/L		WAR0447(
5436	Chlorpyrifos	TRUE	Include	Organic	Pesticide	COM	TRUE	5501	0.4	ug/L		WAR0447(
5437	Diazinon	TRUE	Include	Organic	Pesticide	COM	TRUE	5502	0.4	ug/L		WAR0447(
5438	Malathion	TRUE	Include	Organic	Pesticide	COM	TRUE	5503	0.4	ug/L		WAR0447(
5439	Indeno(1,2,3-cd)pyrene	TRUE	Include	Organic	HPAH and cPAH	COM	FALSE	5504	2.4	ug/L		WAR0447(
5440	Benzo(b)fluoranthene	TRUE	Include	Organic	HPAH and cPAH	COM	FALSE	5505	3.1	ug/L		WAR0447(
5441	Acenaphthene	TRUE	Include	Organic	LPAH	COM	FALSE	5506	0.35	ug/L		WAR0447(
5442	Dibenzo(a,h)anthracene	TRUE	Include	Organic	HPAH and cPAH	COM	FALSE	5507	1.2	ug/L		WAR0447(
5443	Benzo(k)fluoranthene	TRUE	Include	Organic	HPAH and cPAH	COM	FALSE	5508	3.1	ug/L		WAR0447(
5444	Chrysene	TRUE	Include	Organic	HPAH and cPAH	COM	FALSE	5509	4.5	ug/L		WAR0447(
5445	1-Methylnaphthalene	TRUE	Include	Organic	PAH	COM	TRUE	5510	0.1	ug/L		WAR0447(
5446	Fluorene	TRUE	Include	Organic	LPAH	COM	FALSE	5511	0.52	ug/L		WAR0447(
5447	Benzo(g,h,i)perylene	TRUE	Include	Organic	HPAH	COM	FALSE	5512	2.7	ug/L		WAR0447(
5448	Pyrene	TRUE	Include	Organic	HPAH	COM	FALSE	5513	8.2	ug/L		WAR0447(
5449	Acenaphthylene	TRUE	Include	Organic	LPAH	COM	TRUE	5514	0.1	ug/L		WAR0447(
5450	2-Methylnaphthalene	TRUE	Include	Organic	SVOC	COM	TRUE	5515	0.1	ug/L		WAR0447(
5451	Anthracene	TRUE	Include	Organic	LPAH	COM	FALSE	5516	1.4	ug/L		WAR0447(
5452	Benz(a)anthracene	TRUE	Include	Organic	HPAH and cPAH	COM	FALSE	5517	4.1	ug/L		WAR0447(
5453	Benzo(a)pyrene	TRUE	Include	Organic	HPAH and cPAH	COM	FALSE	5518	3.8	ug/L		WAR0447(

Comparison with other studies



Generally lower than national stormwater datasets from the 80's and higher than Puget Sound Toxics Loading Study

‘Non-detect’ or censored data



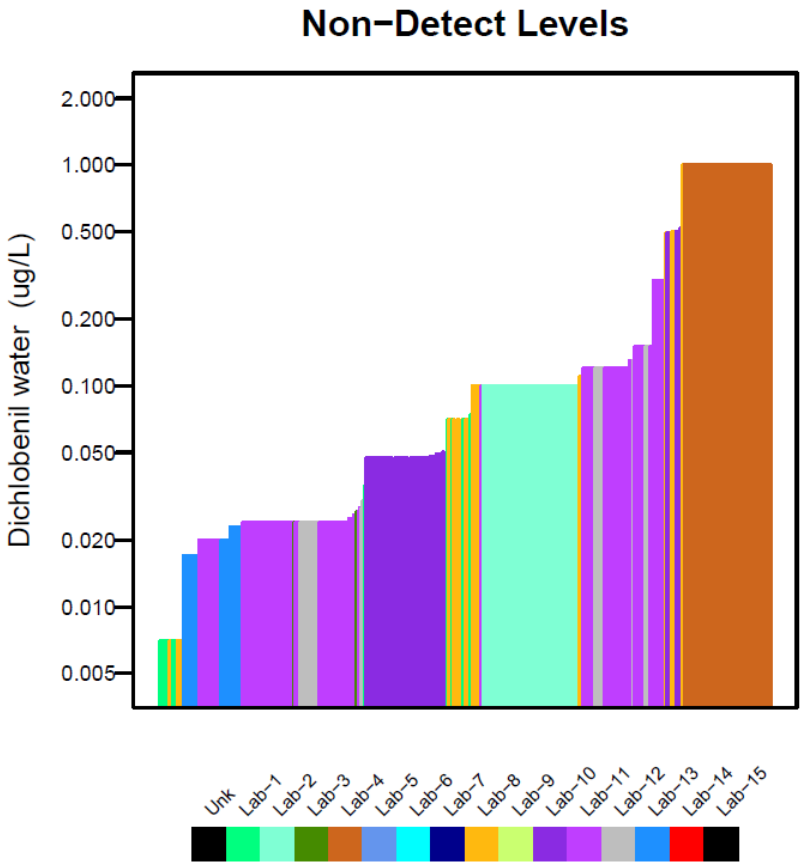
- laboratory defined data qualifiers were used in the analysis to identify ‘non-detects’.

Case A: 88 parameters
Case B: 31 parameters
Case C: 53 parameters

- total parameters includes both water and sediment
- Case A and B parameters are suitable for statistical summary

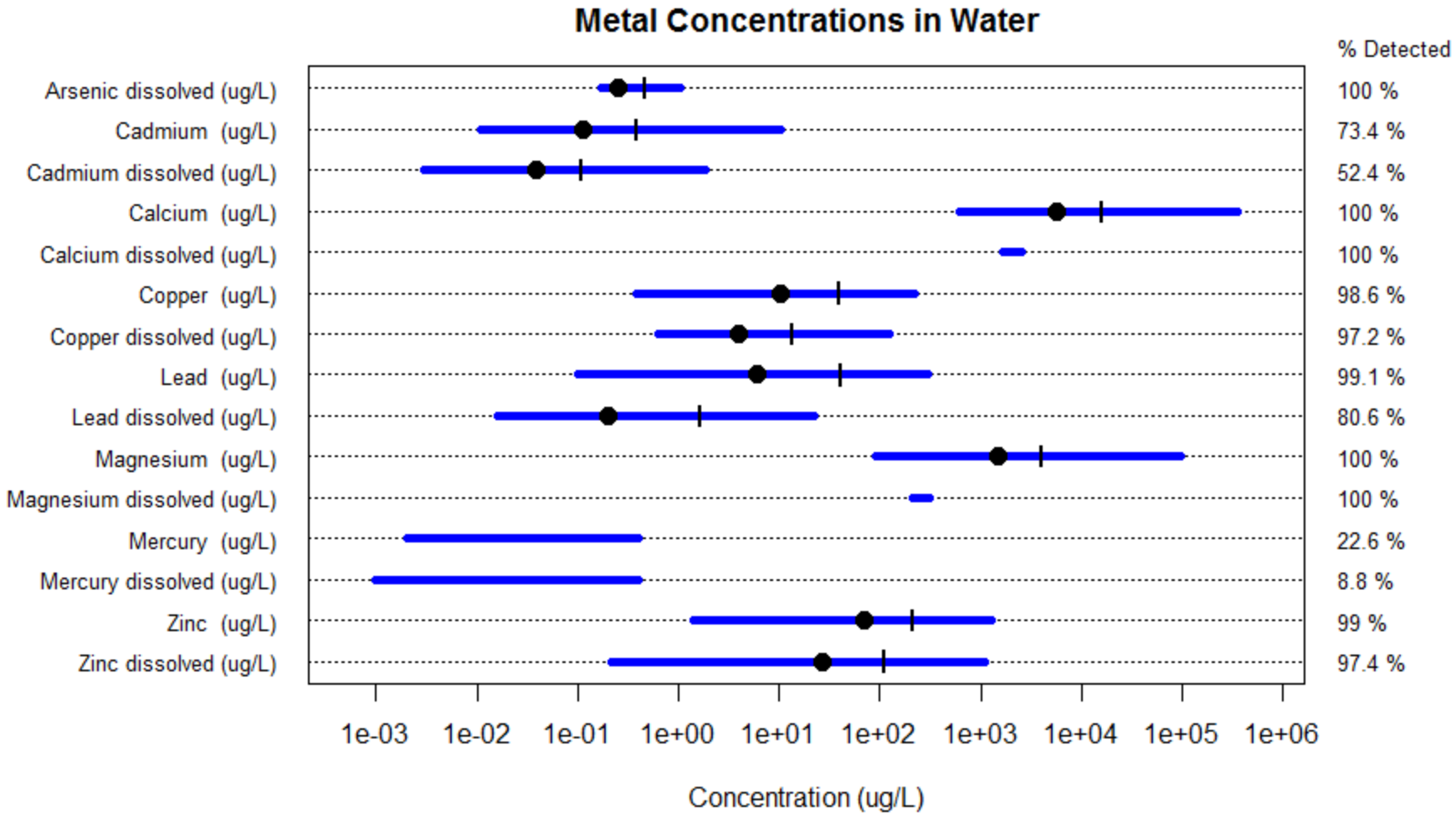
Variation in reporting limits

- function of laboratory capabilities, cleanliness of the sample, variability of the analyte in the sample, and volume of sample collected.
- target reporting limits in the Permit (range).
- typically greater for organic parameters

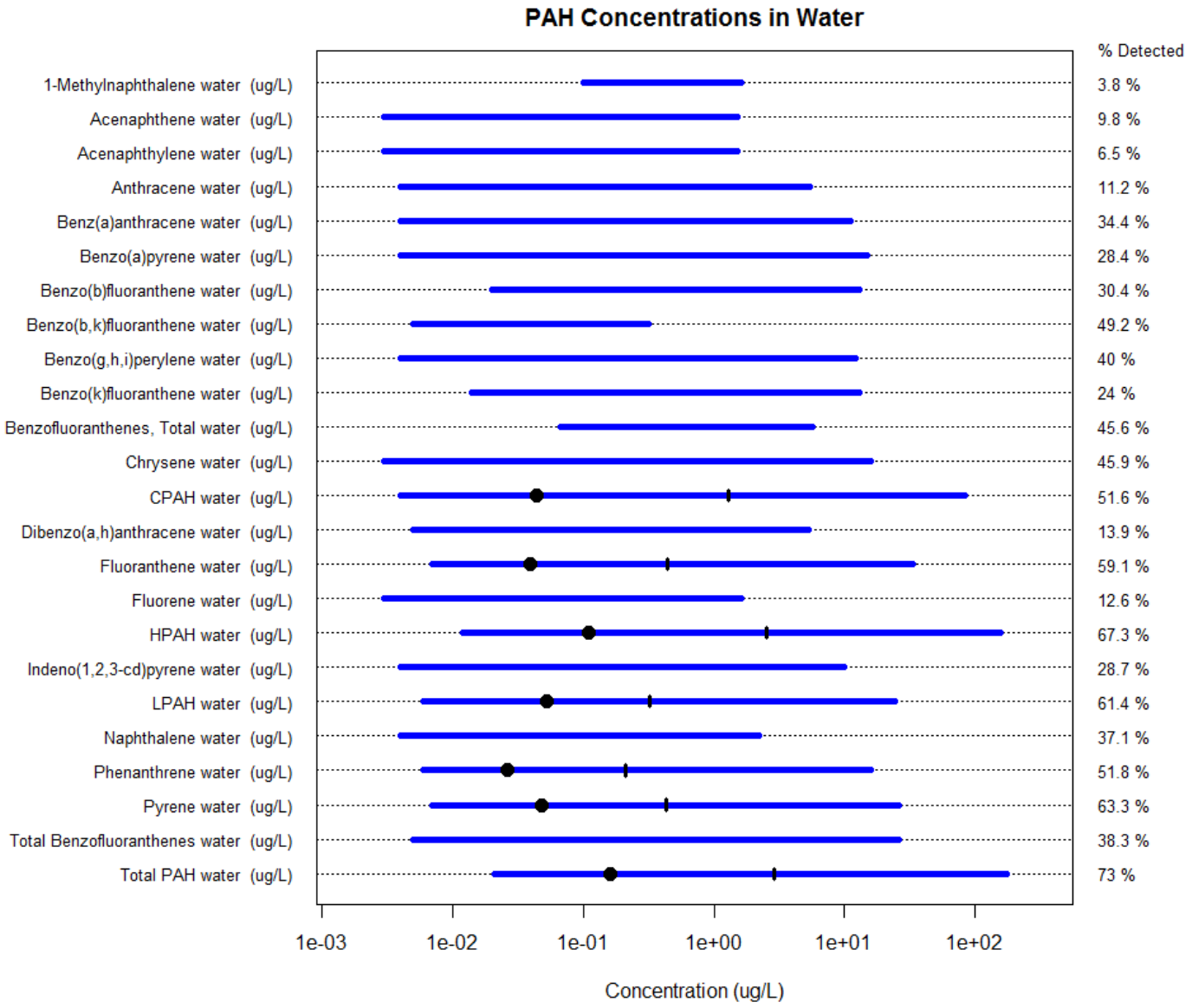


Parameter statistical summaries

- range of the data (blue bar)
- median (black dot) and 90th percentile (black segment)



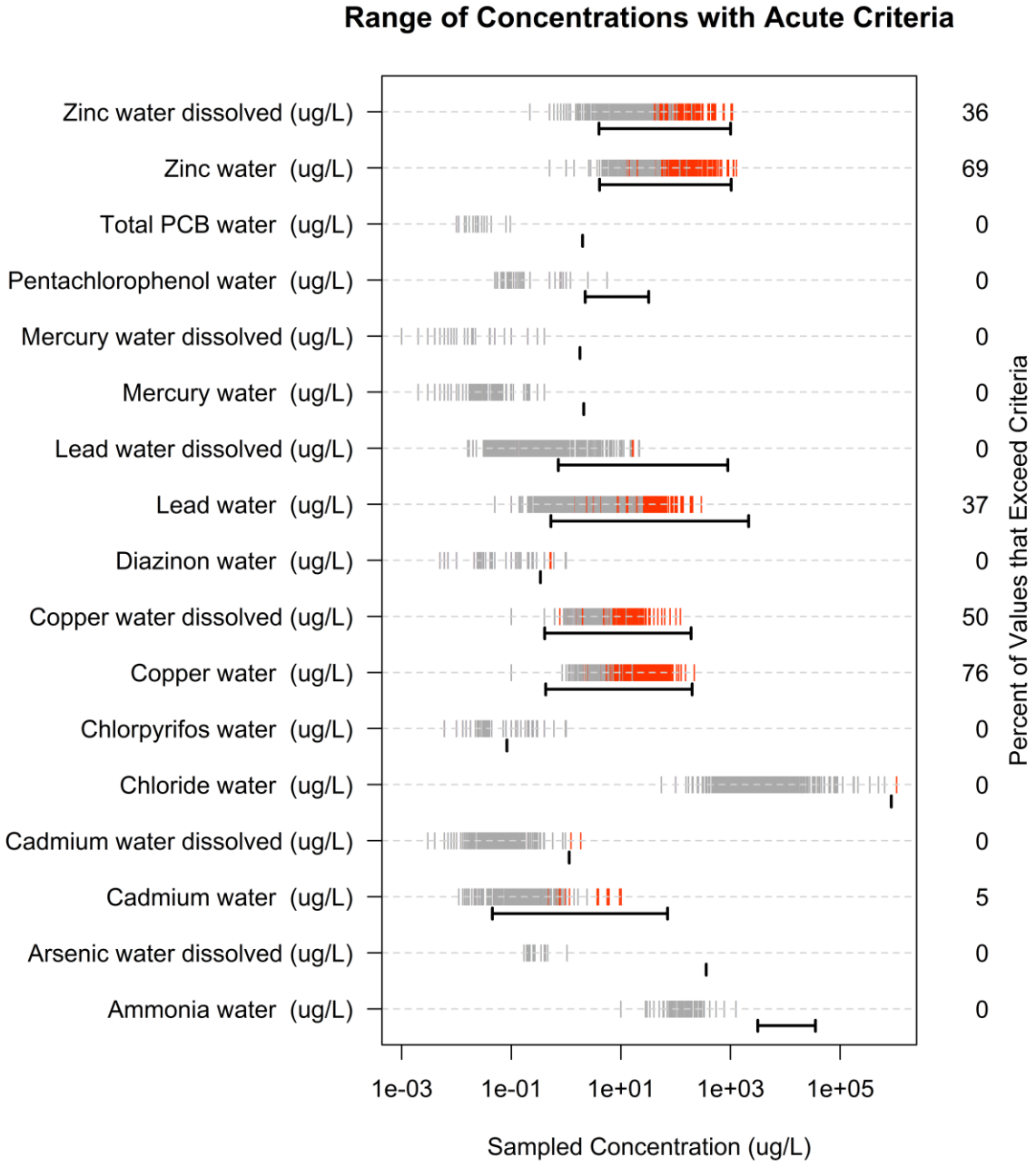
Parameter statistical summaries



Water Quality Criteria

- zinc and copper routinely exceed the acute aquatic life criteria

Reminder: criteria included for context not compliance

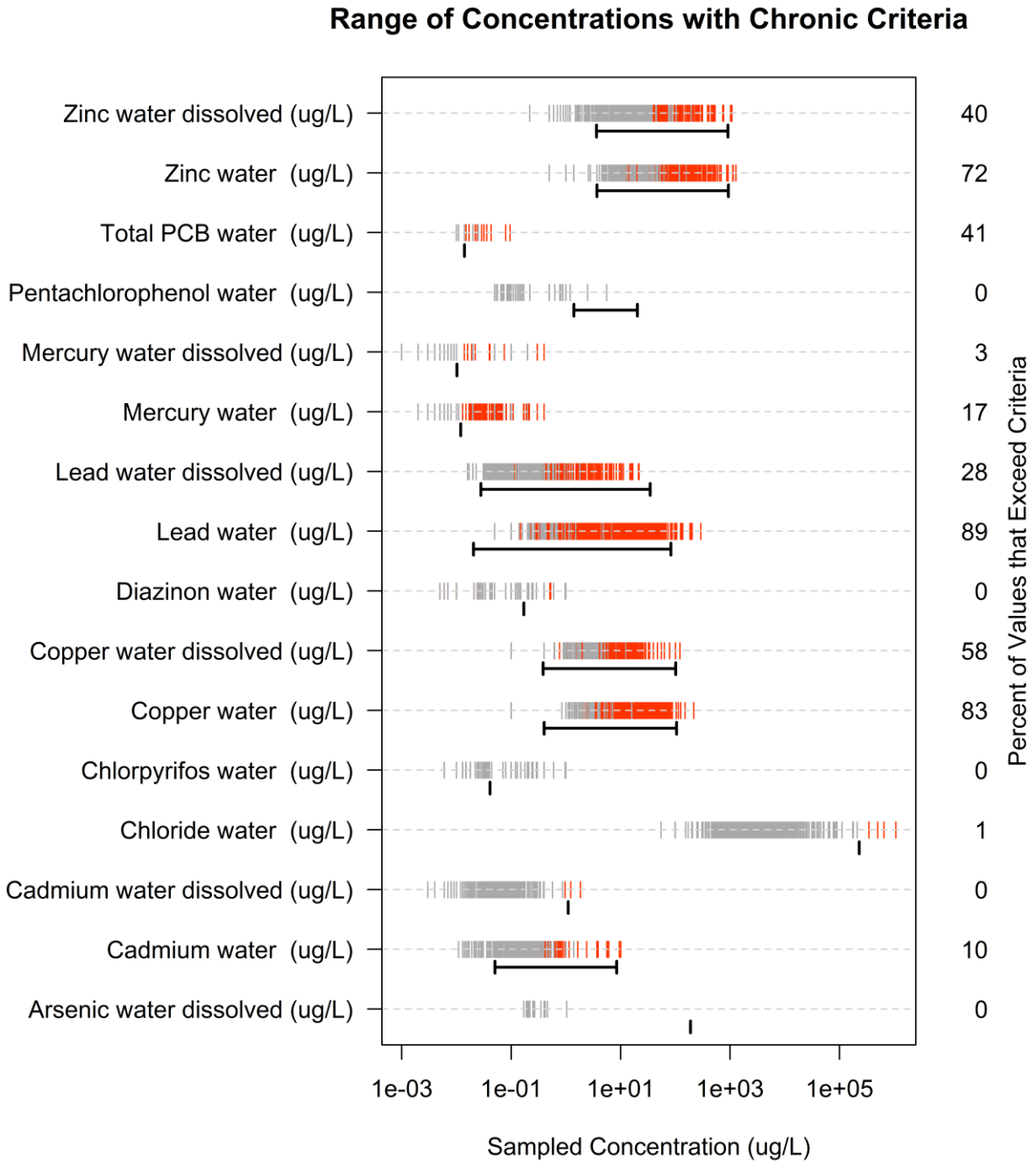


Water Quality Criteria

- zinc, copper and lead routinely exceed the chronic aquatic life criteria

- total PCBs and mercury were noted to exceed the chronic aquatic life criteria

Reminder: criteria included for context not compliance



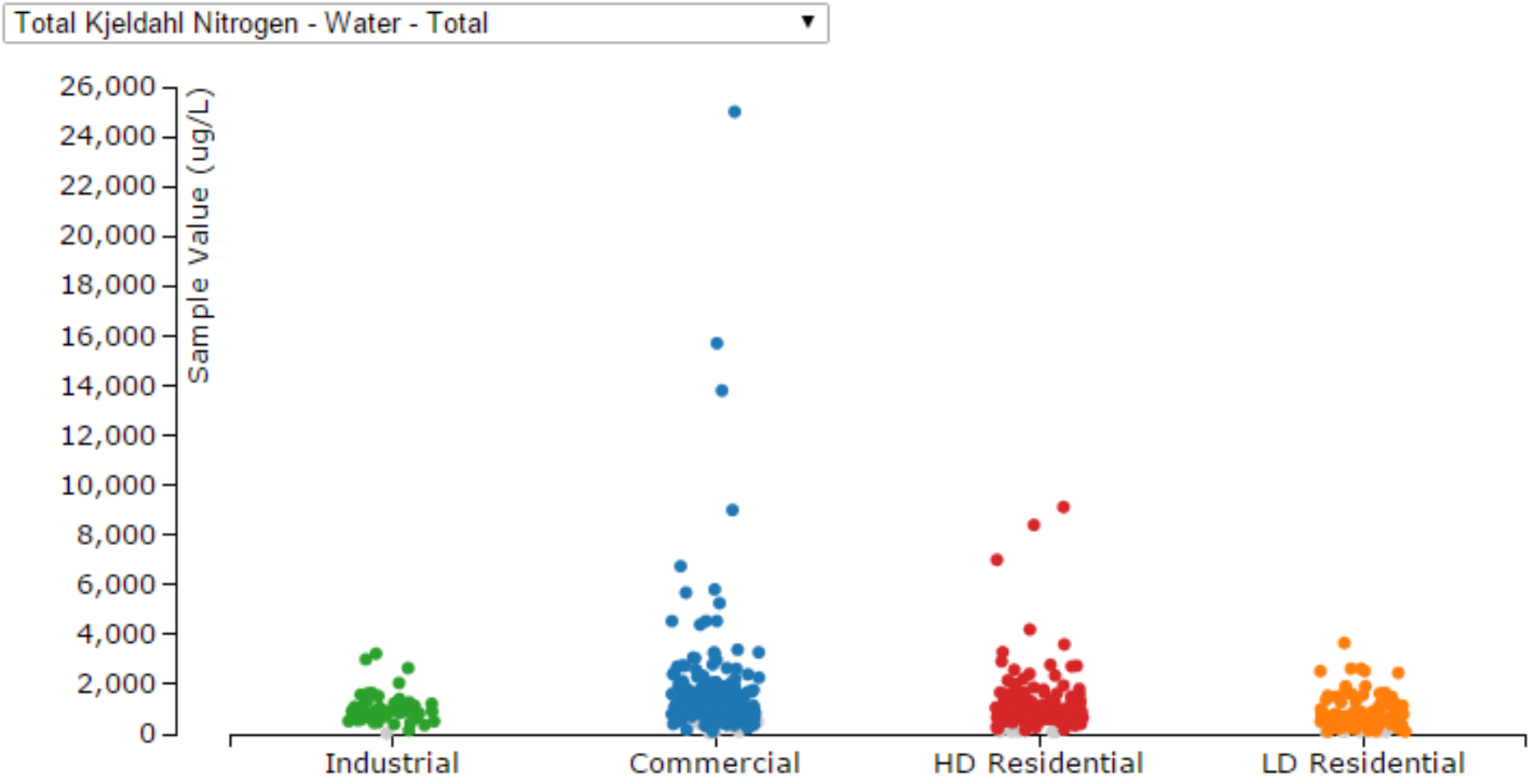
Key Results - Nutrients

water quality criteria for **ammonia** were **not exceeded**

dry season concentrations were **higher** for all nutrients

nutrients showed **strong** and **different** land use associations

- total phosphorus was highest in Industrial areas
- TKN was higher in Commercial and Industrial land uses
- dissolved nutrients were significantly greater from residential land uses


Total Kjeldahl Nitrogen - Water - Total
Sample Value (ug/L)
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Industrial
Commercial
HD Residential
LD Residential

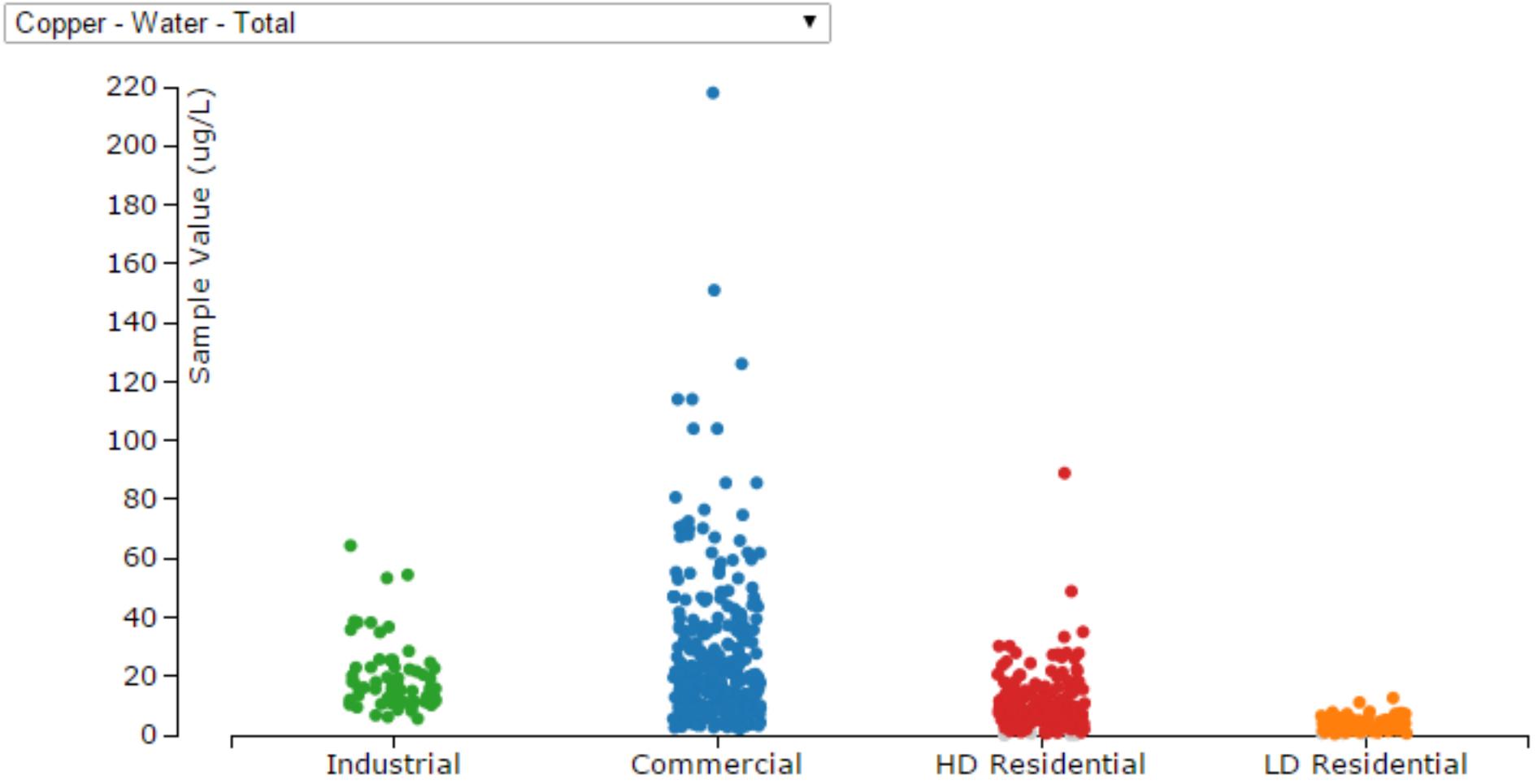
Key Results - Metals

metals were **most likely to exceed** water quality criteria for aquatic life

- **copper**, **zinc** and **lead** most frequent
- cadmium occasionally

commercial and industrial areas **highest** stormwater concentrations for metals

metals were statistically **higher** in the **dry season** storms indicating they "build-up" with dry periods.

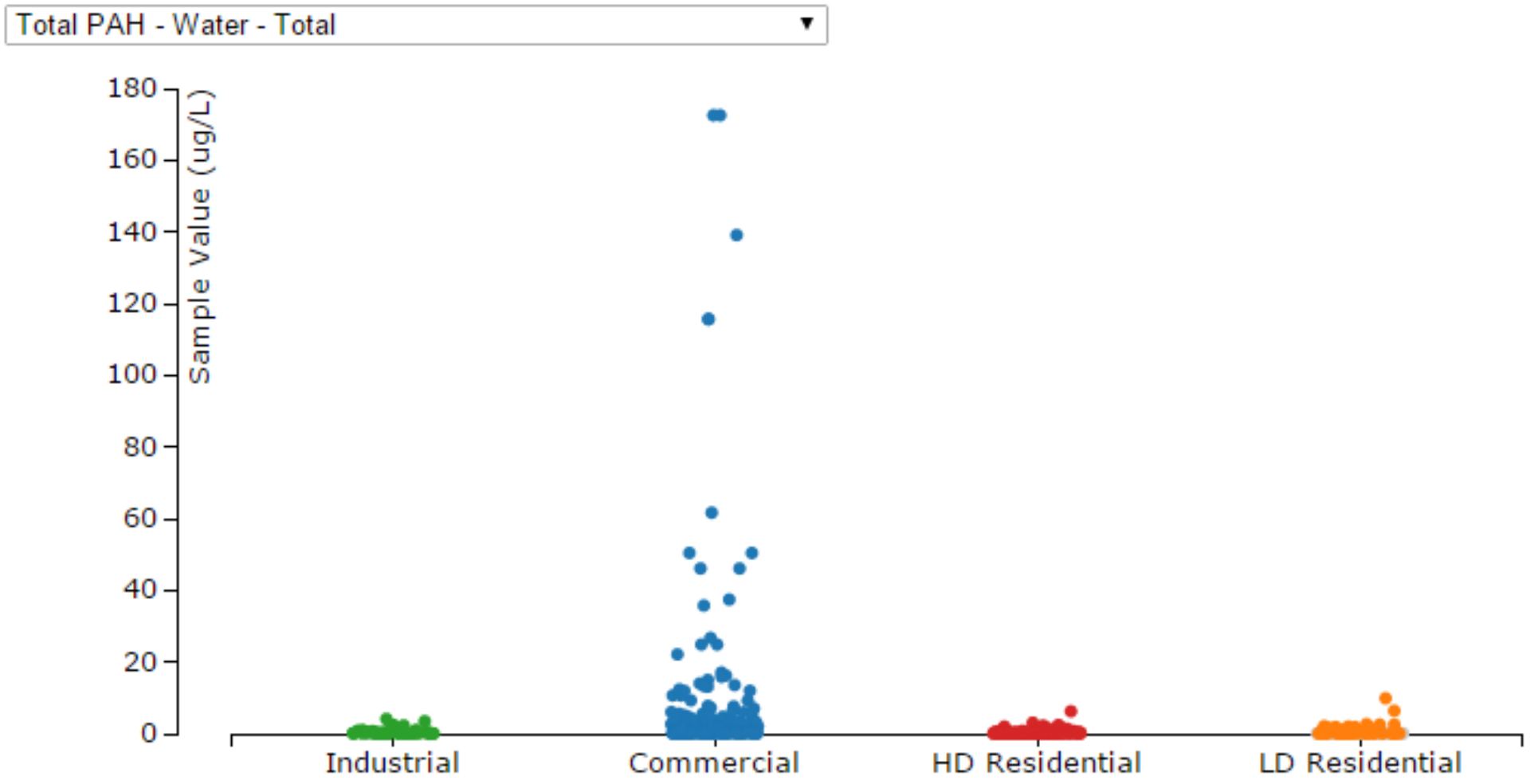

Copper - Water - Total
Sample Value (ug/L)
220
200
180
160
140
120
100
80
60
40
20
0
Industrial
Commercial
HD Residential
LD Residential

Key Results - Organics

PAHs, phthalates and PCBs did not "build-up" in dry periods

PAHs, NWTPH-Dx and BEHP were found **in all samples** (water and sediment)

- diesel much higher in commercial industrial basins
- motor oil higher from residential basins


Total PAH - Water - Total
Sample Value (ug/L)
180
160
140
120
100
80
60
40
20
0
Industrial
Commercial
HD Residential
LD Residential

Land Use – Impervious Area (%)

	Low-Density Residential	High-Density Residential	Commercial	Industrial
Clark County	7	**52**	76	-
Pierce County	**5**	**28**	**96**	-
King County	17	50	80	-
Snohomish County	**26**	40	77	-
City of Tacoma	-	42	**65**	**90**
City of Seattle	-	50	61	**51**
Port of Tacoma	-	-	82	-
Port of Seattle	-	-	95	-

Key Results – Land Uses

Commercial and industrial lands have **higher** concentrations of:

- Metals
- Hydrocarbons
- Phthalates
- Total N and P
- PCBs and pentachlorophenol

Residential land uses discharge **the highest dissolved nutrient** concentrations

Metals, diesel, nutrients "build-up" and are **highest in commercial and industrial** areas in **dry seasons** storms.

Next Steps

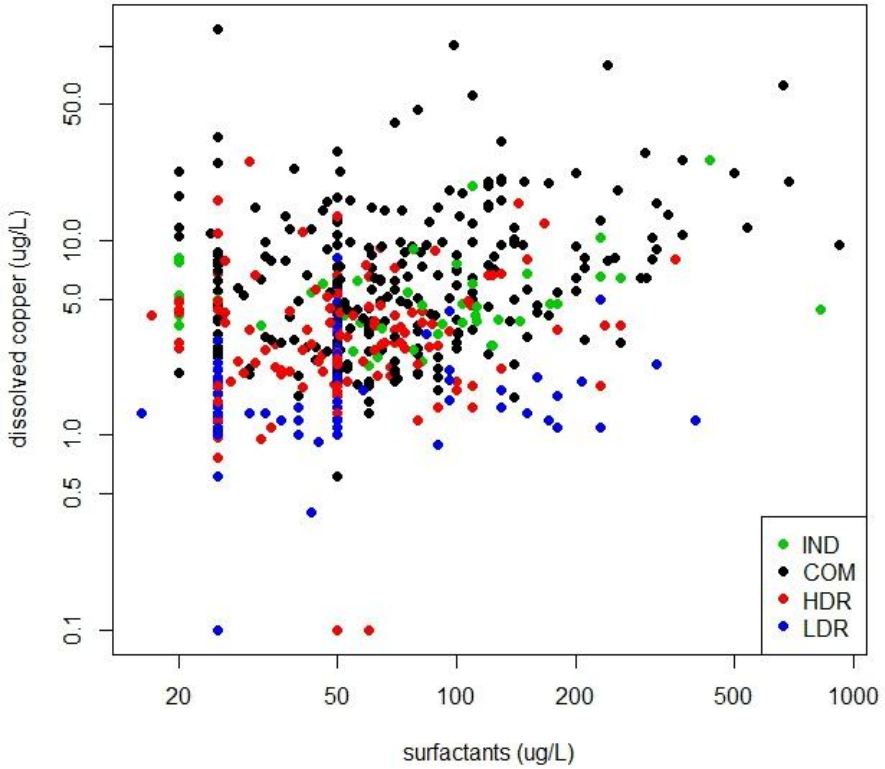
there are additional analyses possible using the existing dataset, or a slightly expanded dataset:

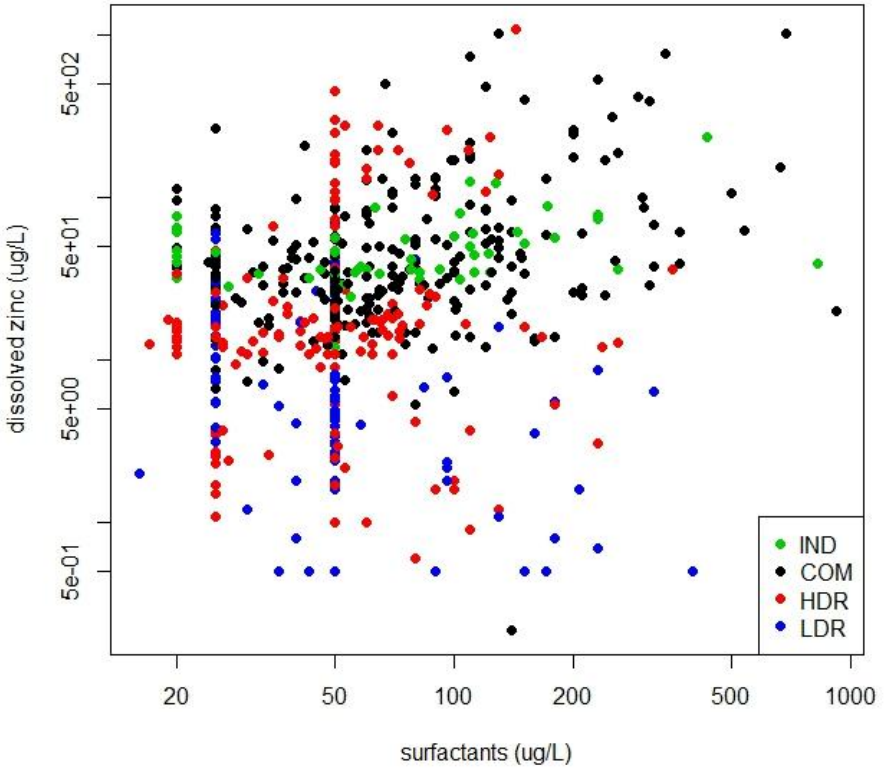
- **correlations** between pollutants
- area load analyses using **annual loads**
- further work with the **toxicity** data

collecting the same data in the future, at the same sites, could expand this snapshot of water quality into a **trends analysis**

integrate lessons learned from this study into **future updates** to the **Stormwater Manual** and the **municipal stormwater permits**

Example of Further Analysis





- Surfactants have a strong relationship with dissolved copper and dissolved zinc in samples from commercial areas ($p<0.001$ in both cases), but not in residential areas
- Surfactants do not appear to have any relationship with total suspended solids ($p=0.21$) or turbidity ($p=0.74$).

Questions

Dataset available at:

http://www.ecy.wa.gov/eim/index.htm (Ecology's EIM database)

Or by contacting report authors

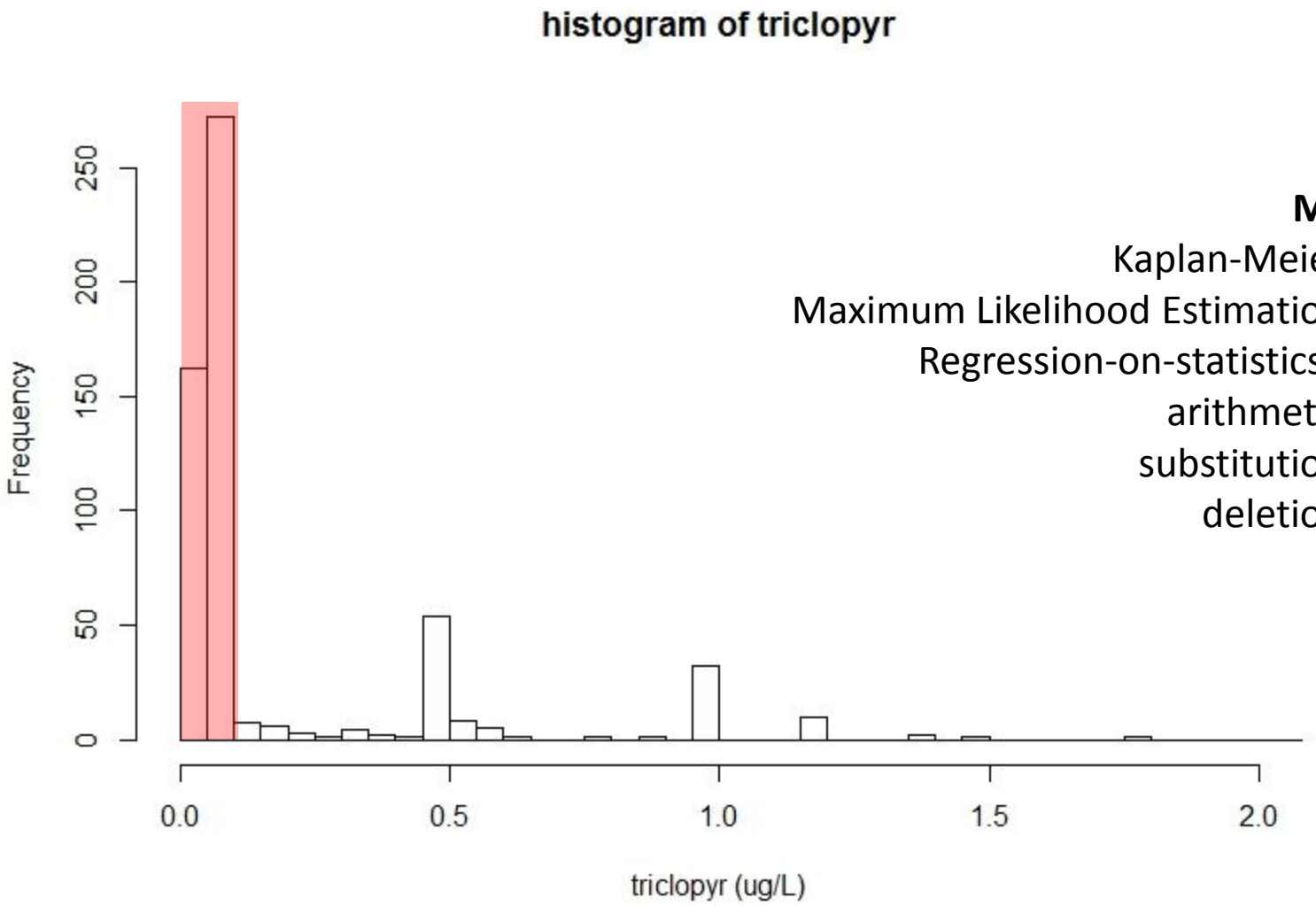
Author contact info:

Brandi Lubliner (bwra461@ecy.wa.gov) – final report corresponding author
Will Hobbs (whob461@ecy.wa.gov) – data analysis and report author
Nat Kale (nkal461@ecy.wa.gov) – permit writer and report author

Extras

Non-parametric Methods

- Case C parameter; 11% detection
- Most appropriate to only show the range of data



Median:

Kaplan-Meier 0.02

Maximum Likelihood Estimation 0.02

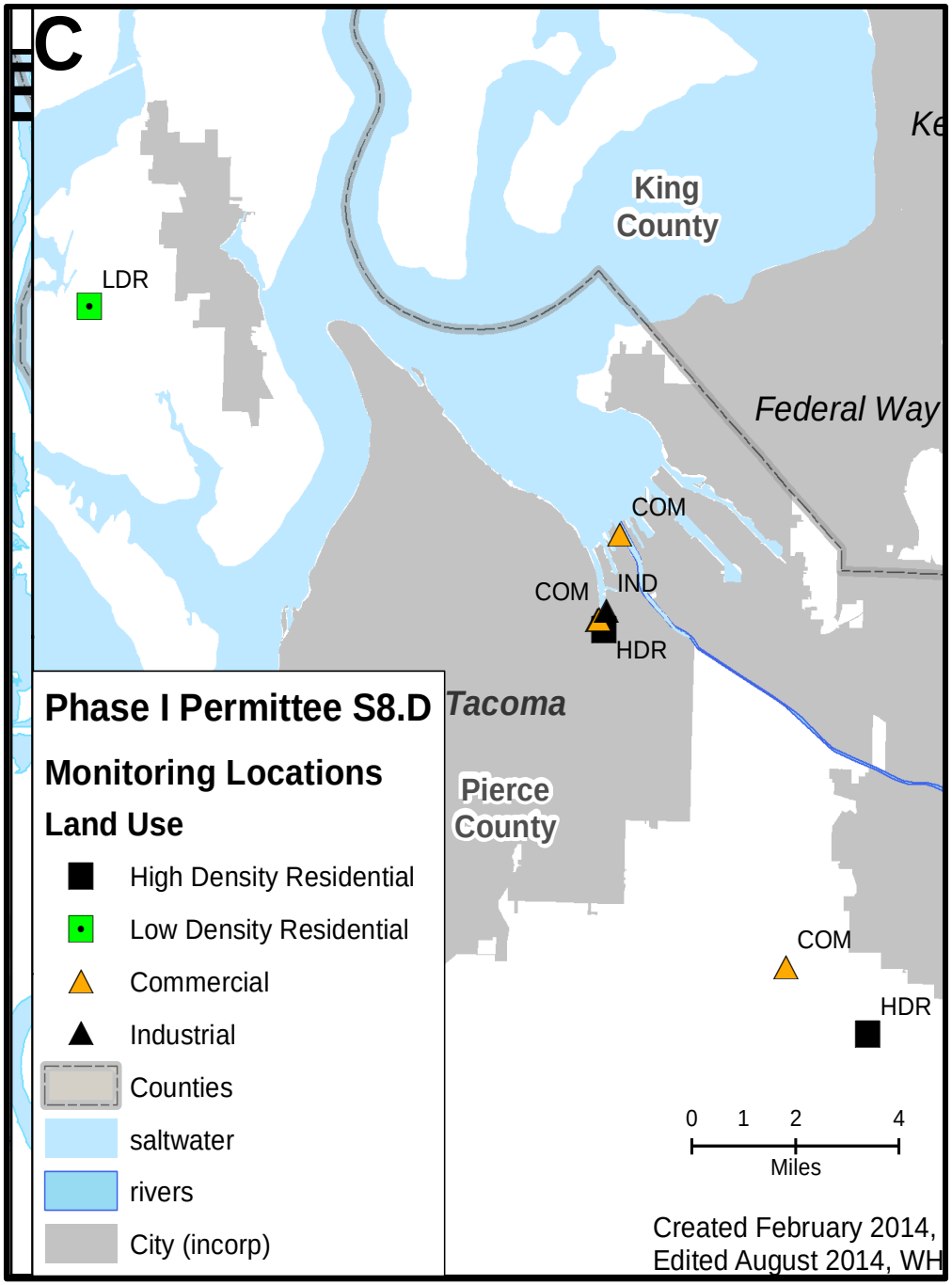
Regression-on-statistics 0.007

arithmetic 0.08

substitution 0.04

deletion 0.11

Permittee Sites



Detection Rates

Parameter in stormwater	% non-detect	Number of samples
Insoluble organics		
Chlorpyrifos	99.8	644
Diazinon	99.1	644
Malathion	98.9	643
Prometon	96.4	607
1-Methylnaphthalene	96.2	290
Acenaphthylene	93.5	634
p-Cresol	92.3	26
Mercury	91.2	444
Acenaphthene	90.2	634
Soluble Organics		
Ethylbenzene	100.0	120
Benzene	99.2	120
BTEX	97.5	120
Toluene	97.5	120
Total Xylenes	99.2	120

Parameter in stormwater sediment	% non-detect	Number of samples
2-Nitrophenol	100.0	23
2,4-Dichlorophenol	100.0	24
2,4,5-Trichlorophenol	100.0	24
2,4,6-Trichlorophenol	100.0	23
Prometon	100.0	15
Chlorpyrifos	98.1	53
Diazinon	98.1	52
Malathion	98.1	53
4-Chloro-3-Methylphenol	95.2	21
4-Nitrophenol	95.2	21
Diethyl phthalate	94.6	56
PCB-Aroclor 1248	93.9	33
2,4-Dimethylphenol	92.9	42
2,4-D	91.7	12
Mecoprop	91.7	12
Triclopyr	91.7	12

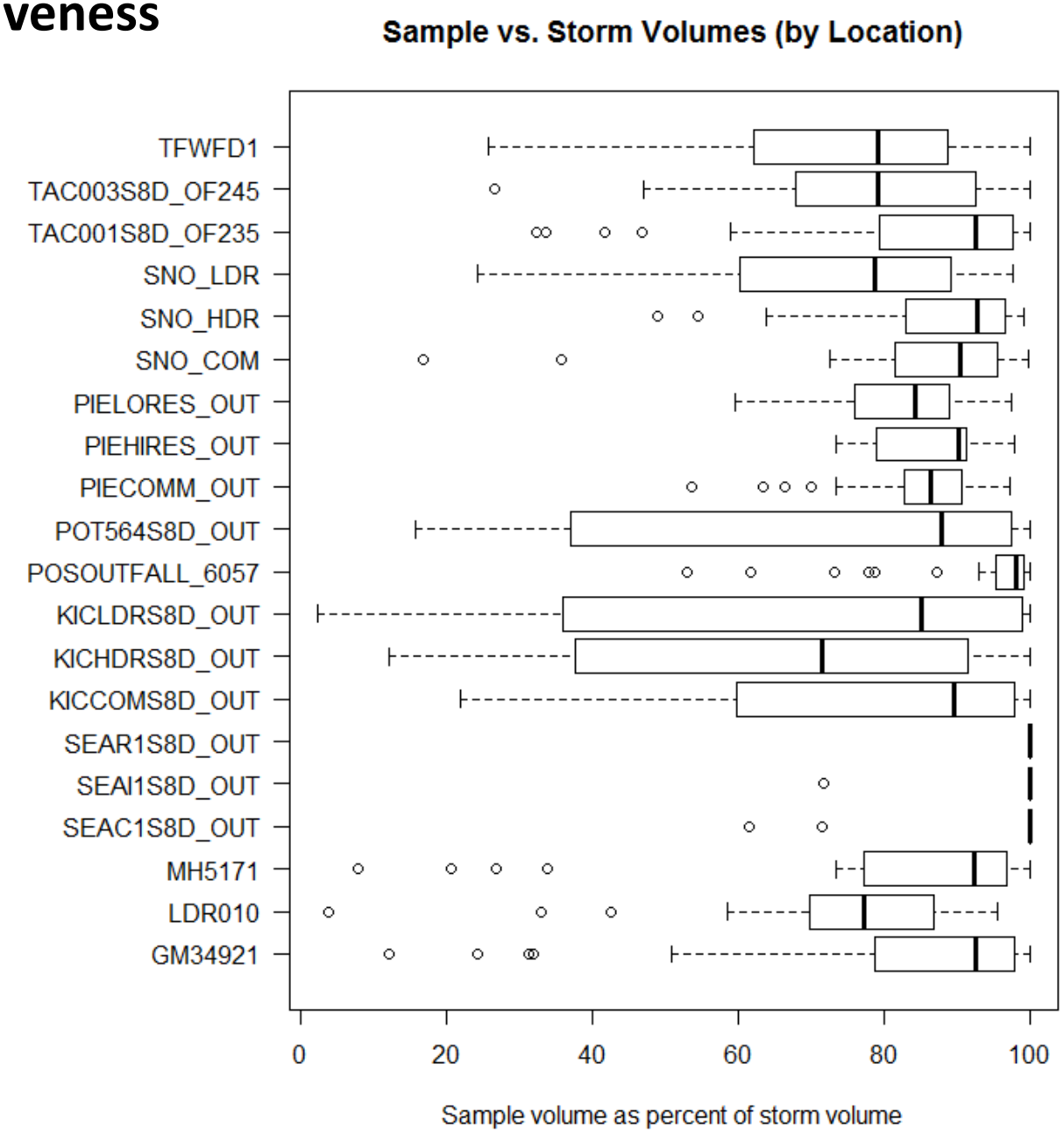
Parameters with >90% non-detect

- volatile or semi-volatile organics, pesticides and mercury had low detection in water
- pesticides and phenols had low detection in sediments

Storm Representativeness

- all samples were in compliance; the vast majority of samples represented 80-90% of the storm

- samples which represented a low % of the storm were collected during longer storms (i.e. still in compliance)



Data Analysis

Statistics for Censored Environmental Data Using Minitab and R (Dennis Helsel, 2012)

- NADA package in R (descriptive and comparison statistics); E. Newell, N. Kale and W. Hobbs
- Vegan package in R (multivariate statistics); W. Hobbs

Classification of each parameter by % non-detect

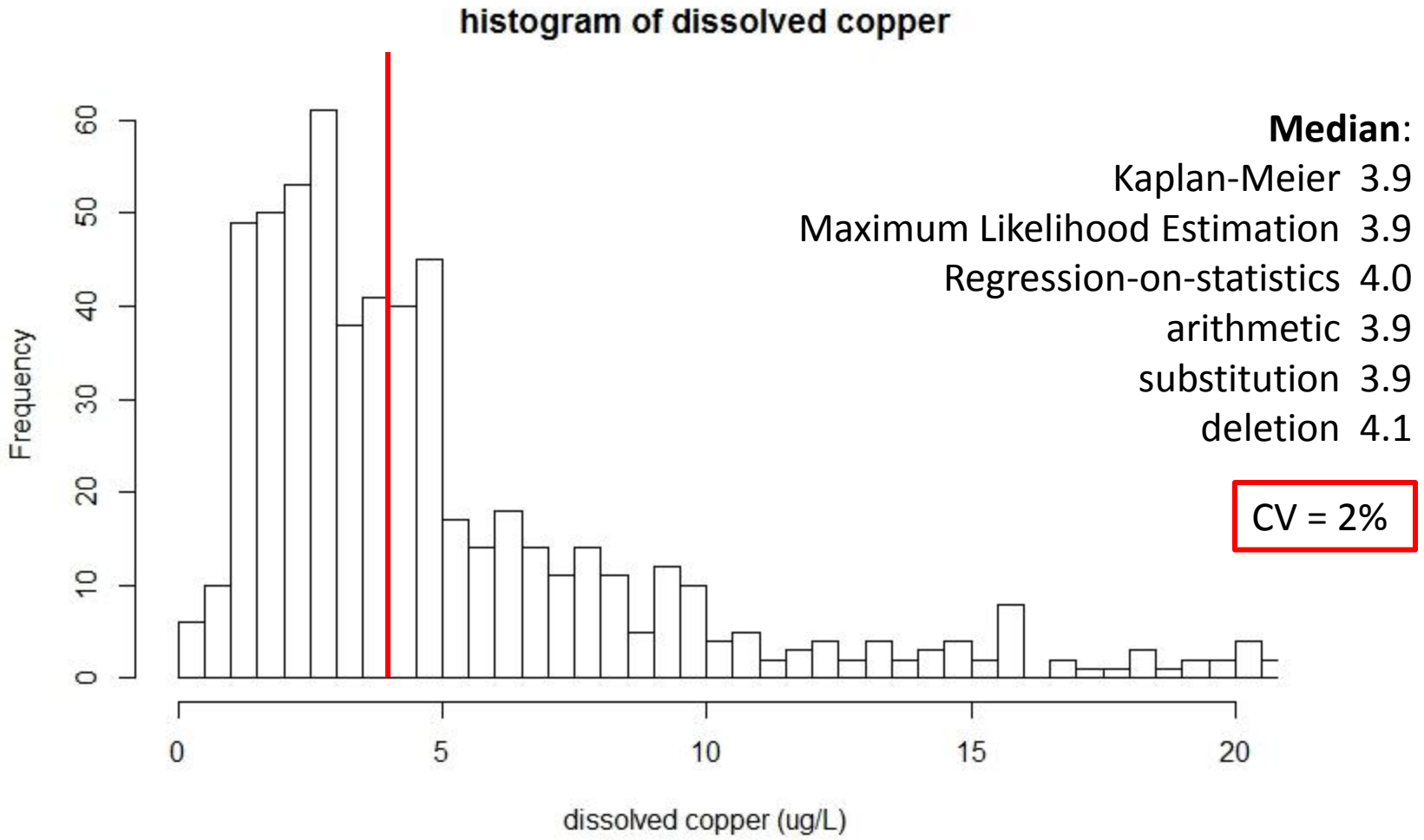
Case	Amount of Data by Parameter		
	Percent non-detect	**<50 Observations**	**> 50 Observations**
A	< 50% non-detects	Kaplan-Meier	Kaplan-Meier
B	50-80% non-detects	Kaplan-Meier Robust MLE, robust ROS	Kaplan-Meier MLE
C	> 80% non-detects	Report ranges or % above a meaningful threshold	Report ranges and high percentile concentrations

Comparison to criteria

- scripts written to compare each individual sample to criteria (N.Kale)

Non-parametric Methods

- distribution-free methods and rank-order statistics
- applied to descriptive statistics (e.g. Kaplan-Meier and Regression-on-statistics) and comparison among groups of data (e.g. Wilcoxon test or peto-prentice test)



Median:

Kaplan-Meier 3.9

Maximum Likelihood Estimation 3.9

Regression-on-statistics 4.0

arithmetic 3.9

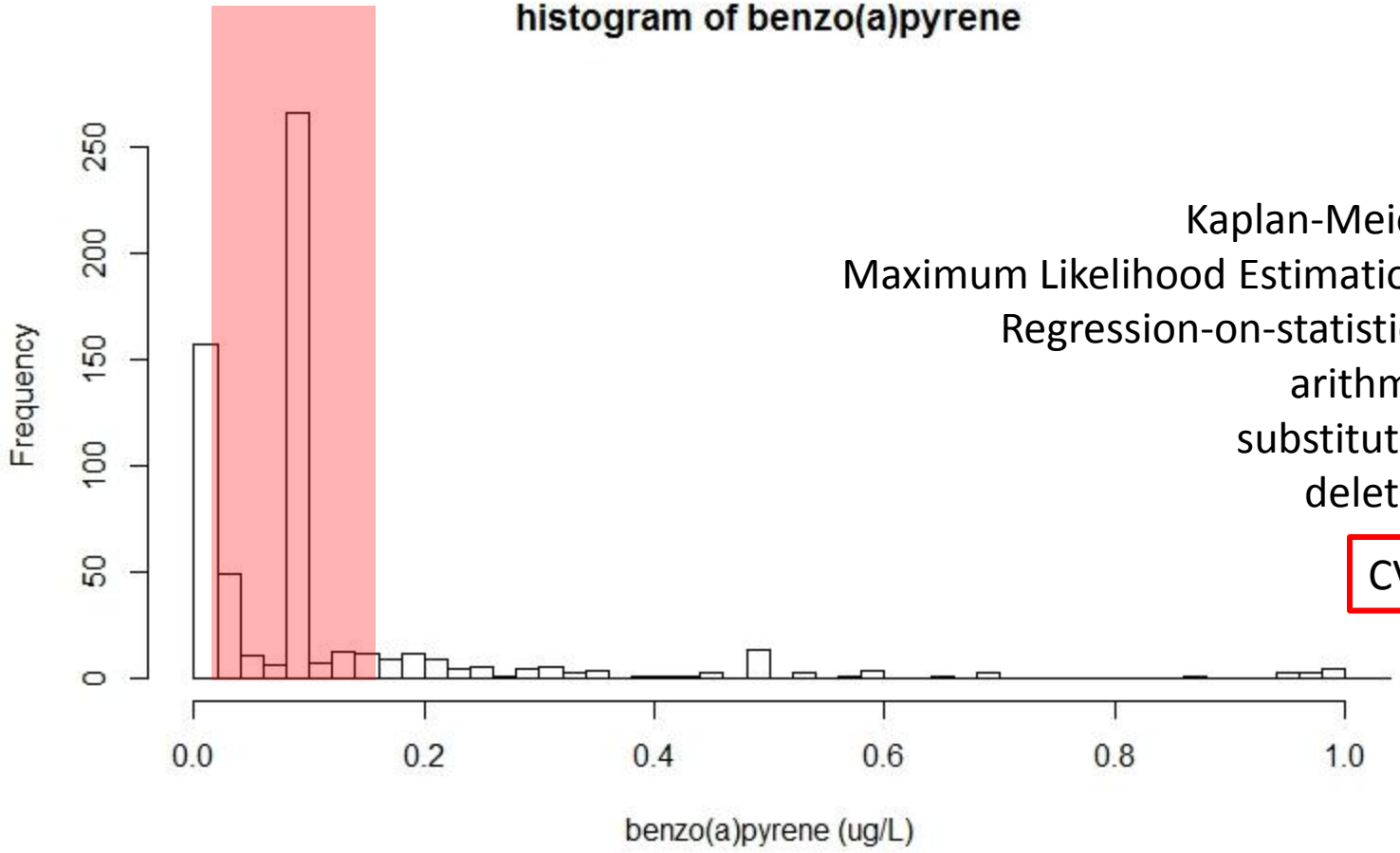
substitution 3.9

deletion 4.1

CV = 2%

Non-parametric Methods

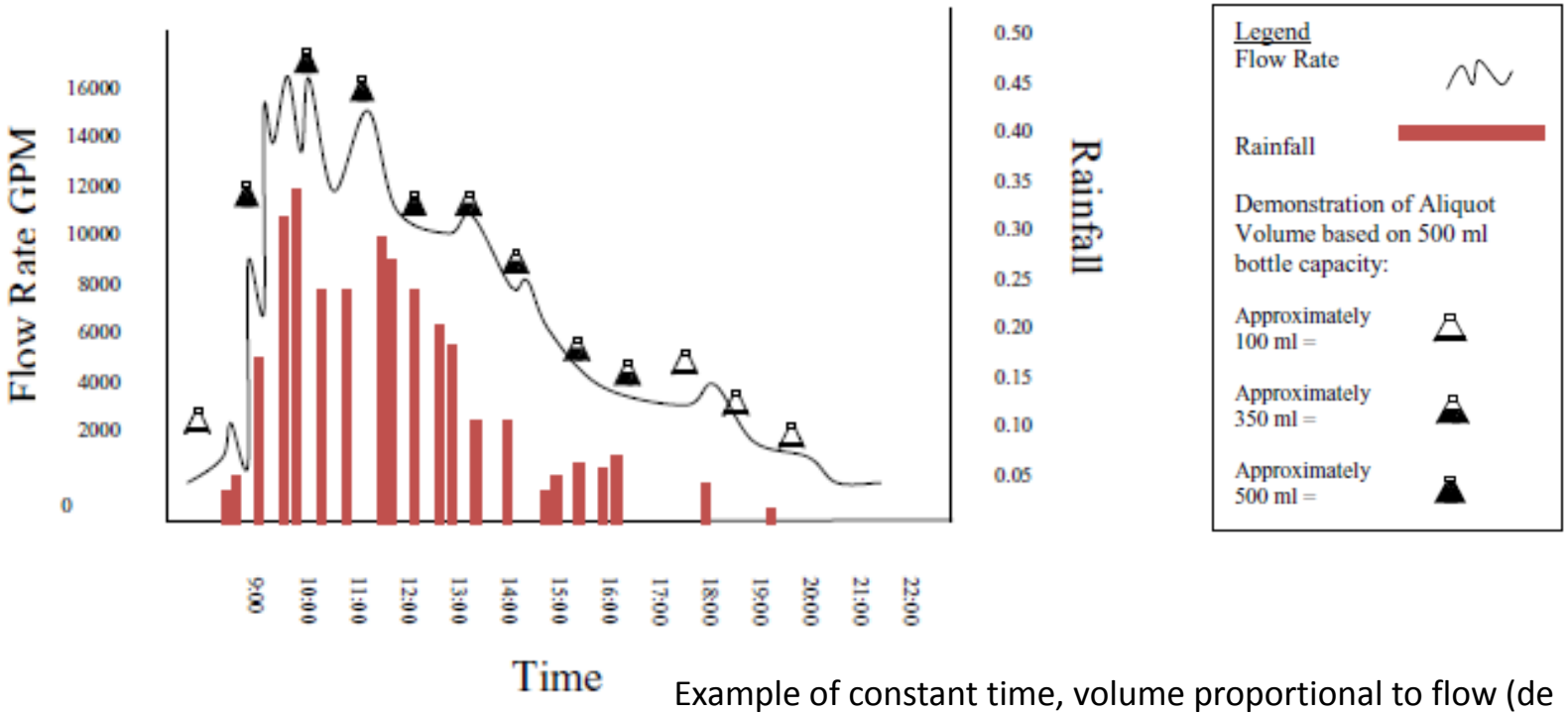
- Case B parameter; 28% detection
- Median overestimated by 1-2 orders of magnitude with substitution or deletion approach



Median:
Kaplan-Meier 0.007
Maximum Likelihood Estimation 0.006
Regression-on-statistics 0.005
arithmetic 0.1
substitution 0.05
deletion 0.15

CV = 114%

Sampling



Example of constant time, volume proportional to flow (de Leon and Lowe, 2009, SOP ECY002 WADOE)

- flow-weighted, automated composite samples for chemistry
- capture 75% of the storm hydrograph, with a minimum of 7 composites in the first 24 hours
- **each sample represents a storm-event concentration**